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The Operational RUC-2

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1. INTRODUCTION

An improved version of the Rapid Update Cycle (RUC-2) is being implemented at the National Centers for Environmental Prediction (NCEP) in late 1997-early 1998 to replace the 60-km RUC (RUC-1, Benjamin et al. 1994) first implemented at NCEP in September 1994. The improvements in the new RUC are pervasive through all parts of the analysis and model and result in a significant advance in performance over the RUC-1.

In this paper, we summarize the key differences between the new and old RUC, provide some verification data for the new RUC, and list future plans.

2. HIGHER FREQUENCY

The RUC-2 runs on a *1-h assimilation frequency* compared to the 3-h frequency of RUC-1. This increase has been made possible by the continued increase in asynoptic data over the United States and surrounding areas. For datasets available hourly such as profilers and surface data, this represents a 3-fold increase in data being assimilated. Aircraft data are assimilated in a 1-h window often much closer to its actual valid time in RUC-2 compared to the 3-h window in RUC-1. Twelve-hour forecasts are run every 3 h in RUC-2, with 3-h forecasts at other times.

The data cut-off time in the 1-h cycle is 20 min after valid time, compared to 1 h 20 min for the RUC-1. This constitutes a full 1-h speed-up in the availability of output from RUC-2 versus RUC-1, an important improvement considering the high-frequency, perishable nature of RUC data.

3. HIGHER RESOLUTION

Horizontal resolution in RUC-2 is *40 km* compared to 60 km for RUC-1. The higher resolution allows considerable improvement in terrain influence on local circulations and orographic precipitation patterns. The domain covered by RUC-2 (a subset of the AWIPS-212 grid on a conic projection) is about 50% larger than that covered by RUC-1 (polar projection). More ocean area is also covered in the new RUC-2 domain (Fig. 1).

The RUC-2 has *40 vertical levels* compared to 25 levels in RUC-1. The RUC-2 continues to use a generalized vertical coordinate configured as a hybrid isentropic-sigma coordinate in both the analysis and model. This coordinate has proven to be very advantageous in RUC-1 in providing sharper resolution near fronts and the tropopause and improved moisture transport. A sample cross section of RUC-2 native levels is displayed in Fig. 2. The typical RUC-2 resolution near fronts is apparent in this figure, as well as the tendency for more terrain-following levels to “pile up” in warmer regions (the eastern part of the cross section, in this case). The minimum potential temperature spacing (through much of the troposphere) is 2 K instead of 4 K as in RUC-1. The top level in RUC-2 is at 450 K as opposed to 410 K in RUC-1. Overall, the vertical resolution is somewhat higher both in the boundary layer and free atmosphere, and the domain extends farther into the stratosphere.

Fig.1. Domain and terrain for the 40-km RUC-2. Topography is shown with 200 m contours.

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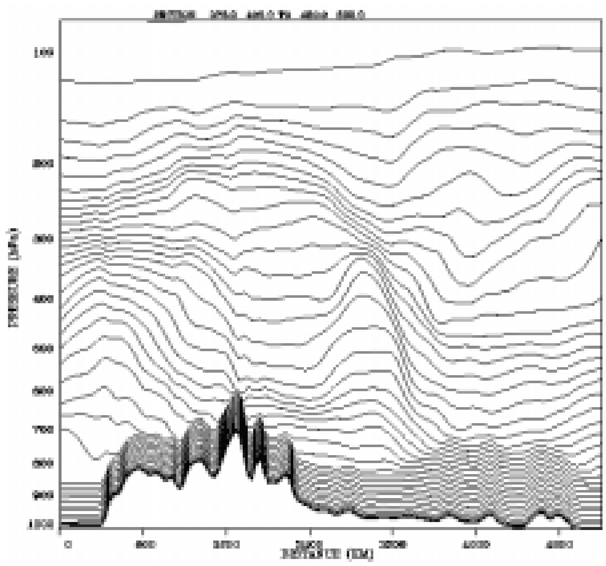

Figure 2. RUC-2 native hybrid isentropic-sigma coordinate levels in a W-E cross section valid at 1500 UTC 9 October 1997 through Oregon, Wyoming (highest terrain is the Absarokas), South Dakota, and eastward through southern Maine.

4. NEW DATA SETS

The RUC-2 uses several new types of observational data not incorporated into RUC-1, including VAD (Velocity Azimuth Display) wind profiles from WSR-88D radars, total precipitable water values from GOES, GOES cloud-drift winds, boundary-layer (915 MHz) profiler winds, and temperatures from RASS (Radio Acoustic Sounding System). Additional information on new wind data in the RUC-2 is given by Smith and Benjamin (1998).

New, more accurate specifications of the land and water surface have also been incorporated into RUC-2. These include

● Daily 50-km resolution sea-surface temperatures- NCEP

● Daily 14-km resolution lake-surface temperatures for the Great Lakes - NOAA/Great Lakes Environmental Research Laboratory

● Daily snow cover/depth data - USAF/NCEP. A snow melting/accumulation algorithm (Smirnova et al. 1998) in RUC-2 forecasts evolution of snow cover over each 24-h period and ongoing snow temperature.

● Monthly 0.14^{o} latitude vegetation fraction data - NESDIS/NCEP

5. IMPROVED ANALYSIS

The optimal interpolation multivariate analysis used in RUC-1 has been substantially modified for the initial RUC-2, providing, among other things, closer fit to observations, better use of aircraft ascent/descent winds and temperatures, and greater efficiency. Levels at and near the surface are subjected to both multivariate and subsequent univariate wind analyses. In the RUC-2, hourly surface analyses are produced directly out of the hourly 3-d cycle rather than in a stand-alone system as in RUC-1. The hourly surface analyses from RUC-2 are considerably improved over those from the RUC-1 surface cycle due to quality control using a forecast model rather than persistence, consistency with mesoscale terrain effects from a model forecast background, and weak geostrophic coupling. For all variables, the RUC-2 surface analyses fit surface observations more closely than those from the RUC-1 surface cycle.

The RUC-2 analysis provides *de facto* analyses of cloud variables and soil variables by using the previous 1-h forecast of these variables as initial conditions for the next run. Although use of observations will later provide improved fields for these variables (e.g., Kim and Nychka 1998), this “cycling” provides substantial improvement over zero initial clouds and climatology for soil variables.

A new 3-d variational analysis (Devenyi and Benjamin 1998) is nearing completion for the RUC-2 and will follow the rest of the RUC-2 into operations with a lag time of 2-3 months.

6. IMPROVED MODEL PHYSICS

To provide improved short-range forecasts of precipitation, surface conditions, clouds, icing and turbulence, the RUC-2 has incorporated state-of-the-art physics parameterizations in the following four areas:

Cloud microphysics. The level 5 microphysics scheme (Reisner et al. 1997) from the NCAR/PSU MM5 model has been incorporated into the RUC-2, providing explicit forecasts of mixing ratios for cloud water, rain water, snow, ice, and graupel. An additional prognostic variable is the number concentration for ice particles. The incorporation of this scheme into RUC-2 is described in detail by Brown et al. (1998).

Surface physics. A multi-level soil/vegetation/snow module (Smirnova et al. 1997a,b, 1998) runs in the RUC-2, giving much improved forecasts of surface and lower tropospheric conditions. A 1-d soil model with variable soil characteristics, vegetation fraction, and seasonally varying albedo runs at each land grid point with six levels down to 3 m.

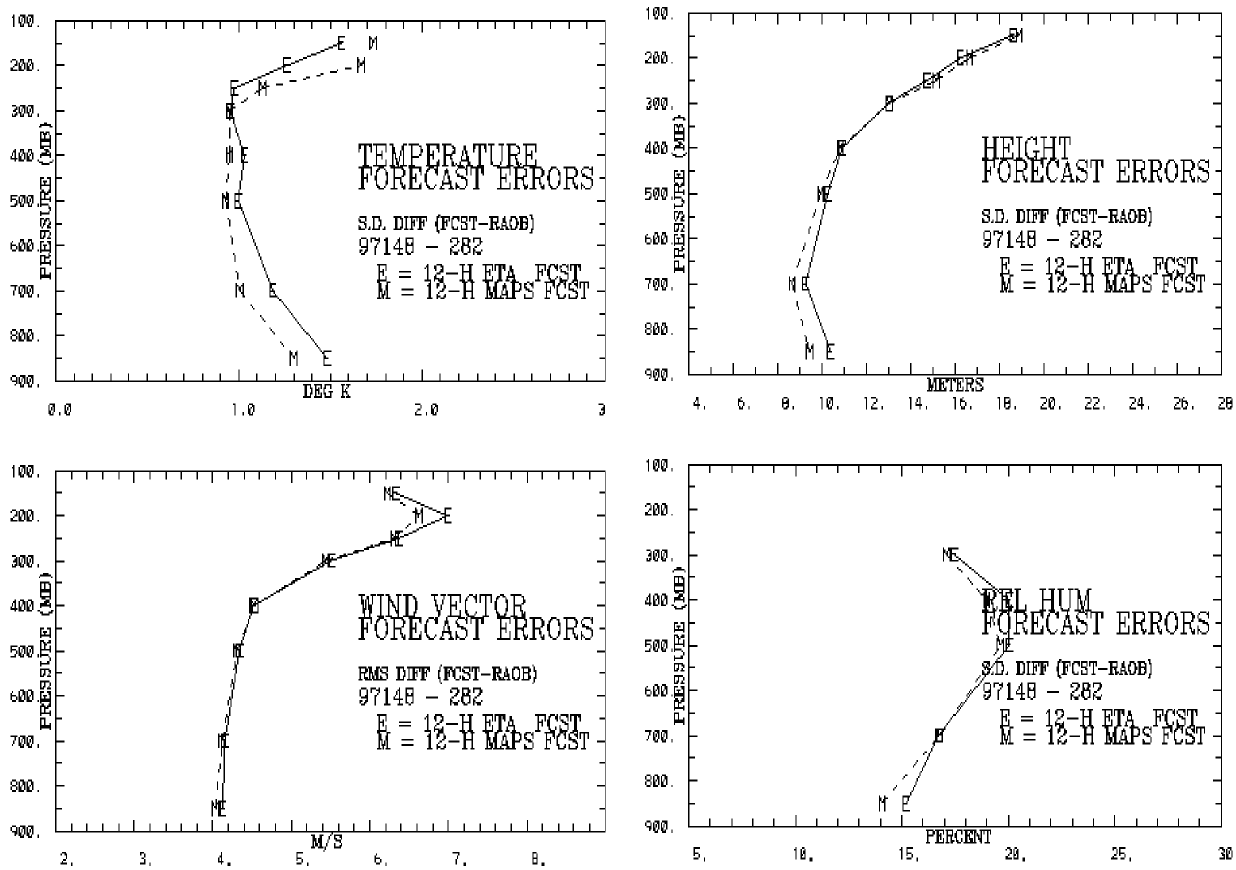

Figure 3. Verification statistics (standard deviation difference or RMS vector difference for winds) for 12-h forecasts against rawinsonde observations for the 40-km RUC-2 and the 48-km Eta. Period is for 28 May - 9 October 1997.

Soil moisture and temperature have been cycled since April 1996 in a test version of RUC-2, producing, after many months, very reasonable estimates of these fields (Smirnova 1997a). Output from this scheme in RUC-2 includes not only improved estimates of surface fluxes, but also a variety of other fields including runoff at the surface and snow melt.

Turbulence. The Mellor-Yamada level-3.0 scheme of Burk and Thompson (1989) has also been incorporated into the RUC-2. This scheme provides explicit forecasts of turbulence kinetic energy, which show considerable potential for improved forecasts of clear-air turbulence (Marroquin et al. 1998).

Radiation. The RUC-2 uses the atmospheric long-wave and short-wave component also from the MM5 model (Dudhia 1989). This scheme includes effects of hydrometeor mixing ratios.

7. PERFORMANCE

The 40-km RUC-2 provides somewhat more accurate short-range forecasts of upper-air variables than the 60-km RUC-1. Earlier comparisons between RUC-1 and RUC-2 are presented by Benjamin et al. (1997). Verification against ACARS aircraft reports in the central U.S. indicate an improvement in RMS vector error of 0.5-1.0 ms^{-1} between RUC-1 and RUC-2 short-range forecasts (Schwartz, personal communication). Three-, 6-, and 9-hour forecasts continue to give significant improvements over 12-h forecasts due to the use of more recent initial conditions using asynoptic data.

In Fig. 3, we present comparisons of 12-h forecast skill between the 40-km RUC-2 and the 48-km Eta model (interpolated to an 80-km grid) for a period from May-October 1997. Overall, the skill of these two models for forecasts of wind, temperature, height, and relative humidity is fairly close. The RUC-2 shows better temperature forecasts, on the average through most of the troposphere, but worse near the tropopause, where a radiation/convection problem caused increased errors. Wind forecasts are similar, but with some improvement from the RUC-2 at the jet level, presumably due to the use of isentropic coordinates. Both height and relative humidity statistics also show some improvement in the lower and middle troposphere for RUC-2 12-h forecasts compared to the Eta. The RUC-2 12-h forecasts initialized at 0000 and 1200 UTC run before the Eta, so they nudge to 24-h Eta forecasts at the boundaries, a handicap related to the start time of the model rather than intrinsic model skill. Certainly the use of Eta forecasts for boundary conditions in RUC-2 is a clear advantage over the NGM (Nested Grid Model) boundary conditions used in RUC-1.

The skill of RUC-2 precipitation forecasts has also been examined by Schwartz and Benjamin (1998). Overall, results indicate more detail in RUC-2 precipitation areas compared to the 48-km Eta, comparable equitable threat score, and lower bias.

8. SUMMARY AND THE FUTURE RUC

A new version of the Rapid Update Cycle, RUC-2, is being brought into operational status at NCEP at the beginning of 1998, culminating 2-3 years of development. The RUC-2 provides considerable improvement over the 60-km RUC-1, in many aspects, including higher spatial resolution, a 1-h cycle, assimilation of new data sets, and incorporation of advanced physical parameterizations.

A field evaluation of the RUC-2 for key users including the Aviation Weather Center in Kansas City, the Storm Prediction Center in Norman, OK, and a number of NWS Forecast Offices will be held in late 1997. A report on the field evaluation with case studies will be made at the January 1998 Conference on Weather Analysis and Forecasting (Schwartz and Benjamin, no paper).

Work is ongoing toward a 3-d variational analysis for the RUC-2 to be implemented in 1998 and an hourly national-scale 3-d cloud analysis. A strong emphasis will be given to assimilation of satellite radiances and drift winds, as well as radar/precipitation data. With the acquisition of a Class-VIII computer at NCEP expected in 1999, the RUC will go to a 20-km horizontal resolution. Further improvements in all physical parameterizations are also expected.

9. ACKNOWLEDGMENTS

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